DEVELOPMENT OF THREE PHASE INDUCTION MOTOR CONTROLLER

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"I hereby acknowledge that the scope and quality of this report is qualified for the award of the Bachelor Degree of Electrical Engineering (Power System)"

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Signature :___________________________

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Date : **22 NOV 2009**

Dedicated to my family and friends who always give me courage to finish this project.

Also thanks to those who have been supportive and the advice through all this time.

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Last but not least, I would like to thank to my parent and friends that gave me lot of moral support while I was doing this project.

ABSTRACT

The development of induction motor controller project is a part of three phase induction motor control system that will be designed based on microcontroller using MC68HC908MR32 integrated circuit manufactured by Motorola. This controller board is an integral part of embedded motion control series and will be interface with power circuit stage, optoisolator and emulator as one system to control a three phase induction motor speed by controlling the PWM output using microcontroller program. The controlled PWM output then will be transfer to power circuit board that consist of power inverter switching to control the speed of the three phase motor. This method is called V/F control method. This control board is equipped with overcurrent circuit sensor to detect fault for safety purpose and tachometer circuit to sense motor speed. This control board also have forward/reverse switch, start/stop switch and speed control pot.

ABSTRAK

Penambahbaikan sidtem kawalan motor tiga fasa yang akan dijalankan di dalam projek ini adalah berdasarkan penggunaan “microcontroller” yang dikeluarkan oleh Motorola. “Contoller Board” ini adalah sebahagian daripada siri kawalan dimana ianya akan disambung kepada litar kuasa, litar “optoisolator” dan litar “emulator” sebagai sati system kawalan untuk mengawal kelajuan motor tiga fasa dengan menggunakan isyarat PWM. Isyarat PWM yang dikawal kemudiannya dihantar kepada litar kuasa yang mengandungi penyongsang arus yang akan mengawal kelajuan motor, kaedah ini dipanggil kawalan voltan dan frequency (V/F). “controller board” ini juga mempunyai litar pengesan kelajuan serta litar pengesan arus berlebihan bagi tujuan keselamatan.

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CHAPTER 1

INTRODUCTION

1.0 Overview

As the prices of the power electronic devices are getting cheaper and widely used in various applications like induction motor controllers, automation, inverters and so on. There are many types of digital controller like a microprocessor, microcontroller and DSP (digital signal processing) are widely used to control algorithm in motor controller. PID, Fuzzy logic, and neural network are the examples of algorithm techniques used in induction motor drive applications. This project was developed with an induction motor controller that use PID controller (proportional–integral–derivative controller) in microcontroller. The PID controller is widely used in the induction motor drive applications due to its simplicity in structure, superior robustness, and familiarity to most field operators. The key issue in designing PID controller for the induction motor drive is to settle the gains so that the controller works well in every condition [5]. Especially in applications like in induction motor controllers not only the frequency, but the magnitude of the voltage needs to be varied [3]. For these kinds of applications pulse width modulated (PWM) are more suitable [3]. The speed of induction motor was varied by controlling the PWM output using microcontroller program.

1.1 Background

A proportional–integral–derivative controller (PID controller) is a generic control loop feedback mechanism (controller) widely used in industrial control systems. A PID controller attempts to correct the error between a measured process variable and a desired setpoint by calculating and then outputting a corrective action that can adjust the process accordingly [6].

The PID controller calculation (algorithm) involves three separate parameters; Figure1 shows Proportional, the Integral and Derivative values. The Proportional value determines the reaction to the current error, the Integral value determines the reaction based on the sum of recent errors, and the Derivative value determines the reaction based on the rate at which the error has been changing. The weighted sum of these three actions is used to adjust the process via a control element such as the position of a control valve or the power supply of a heating element [6].

By "tuning" the three constants in the PID controller algorithm, the controller can provide control action designed for specific process requirements. The response of the controller can be described in terms of the responsiveness of the controller to an error, the degree to which the controller overshoots the setpoint and the degree of system oscillation. Note that the use of the PID algorithm for control does not guarantee optimal control of the system or system stability [5].

Some applications may require using only one or two modes to provide the appropriate system control. This is achieved by setting the gain of undesired control outputs to zero. A PID controller will be called a PI, PD, P or I controller in the absence of the respective control actions. PI controllers are particularly common, since derivative action is very sensitive to measurement noise, and the absence of an integral value may prevent the system from reaching its target value due to the control action [5].

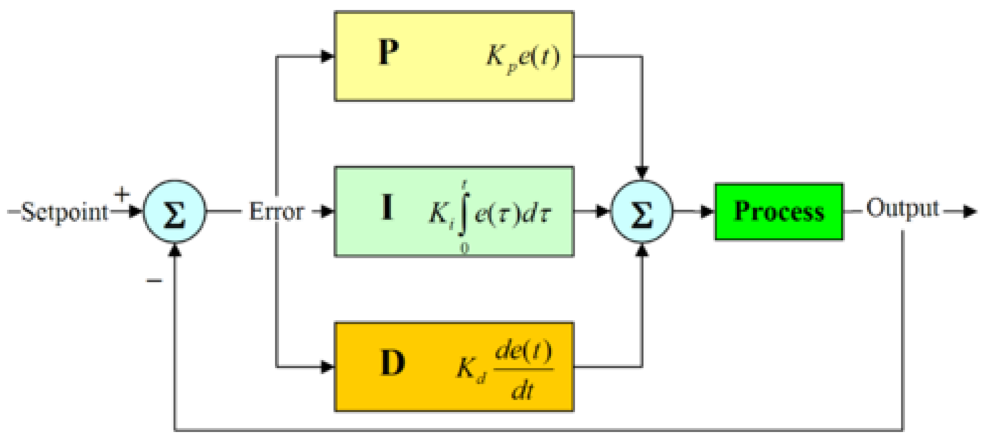


Figure 1

1.2 OBJECTIVE

The aim of this project is to design a controller system to control three phase induction motor using PID controller. In orders to achieve the objective, a few important thing need to be accomplished before the project can be done or continued wich are:

i. To design and fabricate three phase induction motor controller.

ii. To control speed of induction motor by using V/f control method.

iii. To simulate PID Motor Controller system

1.3 SCOPE

This project is focused on two major parts, the hardware and software development. In this project, there are four scopes that were proposed such as below:

i. To design PCB for motor controller board
ii. To simulate PID controller using Matlab
iii. To test the controller using PID algorithm for three phase induction motor.
iv. To analyze the performance of the motor controller based on the simulation result

1.4 PROBLEM STATEMENT

Three-phase induction motors have three salient poles per pole number, so a four-pole motor would have twelve salient poles. This allows the motor to produce a rotating field, allowing the motor to start with no extra equipment and run more efficiently than a similar single-phase motor. The synchronous rotational speed of the rotor is controlled by the number of pole pairs (number of windings in the stator) and by the frequency of the supply voltage. It was difficult to vary the frequency to the motor and therefore the uses for the induction motor were limited. The general term for a power electronic device that controls the speed of motor as well as other parameters is *inverter*. A typical unit will take the mains AC supply, rectify and smooth it into a "link" DC voltage, and, then convert it into the desired AC waveform. In general, a DC-to-AC converter is called an inverter, which is probably where the motor-control *inverter* gets its name. Because the induction motor has no brushes and is easy to control, many older DC motors are being replaced with induction motors and accompanying inverters in industrial applications. But in order to control the switching of power transistor in the inverter, we need to supply PWM signal to the power transistor. To generate this PWM signal, we need to design a controller for example PID controller.

1.5 Organization of the report

There are all five chapters being structures in this repot and every chapter will elaborate in detail about this project. For the first chapter, an overview about this project, three phase induction motor controller using PID is discussed including the objectives, scope and problem statement. This overview is used as a guide line to develop the three phase induction motor controller.

Chapter 2 will explain and discuss on the literature review of the three phase induction motor controller. It also focuses on the general introduction of the controller used. It gives a brief review about the types of controller, and its application in controlling three phase induction motor.

Chapter 3 discusses the methodologies of the controller board that has been applied in completing this project. This chapter gives a detail discussion on the design of the hardware of the systems and the detail explanation and method of creating the printed circuit board (PCB) of the control board. Furthermore, this chapter discuss in detail how the control board work and what method it used to control the speed of three phase induction motor.

Chapter 4 discuss about various testing and results that are conducted to each module of the project. This chapter also concludes the PCB board of the control board including the simulation result of the PWM motor control system using Matlab software. All discussions are concentrated on the result and the overall performance of the three phase inverter.

Lastly, Chapter 5 is discussing on the conclusion and summary of the development of three phase induction motor controller completed project. Some recommendation and system upgrades are also discussed.

CHAPTER 2

LITERATURE REVIEW

2.0 Introduction

This report involved the design and research regarding on three phase induction motor controller. In this chapter, the researcher's review articles and past research about the theory and methods were used in developing three phase induction motor controller.

2.1 Microcontroller

2.1.1 General definitions of microcontroller

Microcontrollers is a small computer on a single integrated circuit consisting of a relatively simple CPU combined with support functions such as a crystal oscillator, timers, watchdog timer, serial and analog I/O etc. it is used in automatically controlled products and devices, such as automobile engine control systems, remote controls, office machines, appliances, power tools, and toys. By reducing the size and cost compared to a design that uses a separate microprocessor, memory, and input/output devices, microcontrollers make it economical to digitally control even more devices and processes. Mixed signal microcontrollers are common, integrating analog components needed to control non-digital electronic systems.[1]

2.1.2 Example of Microcontroller

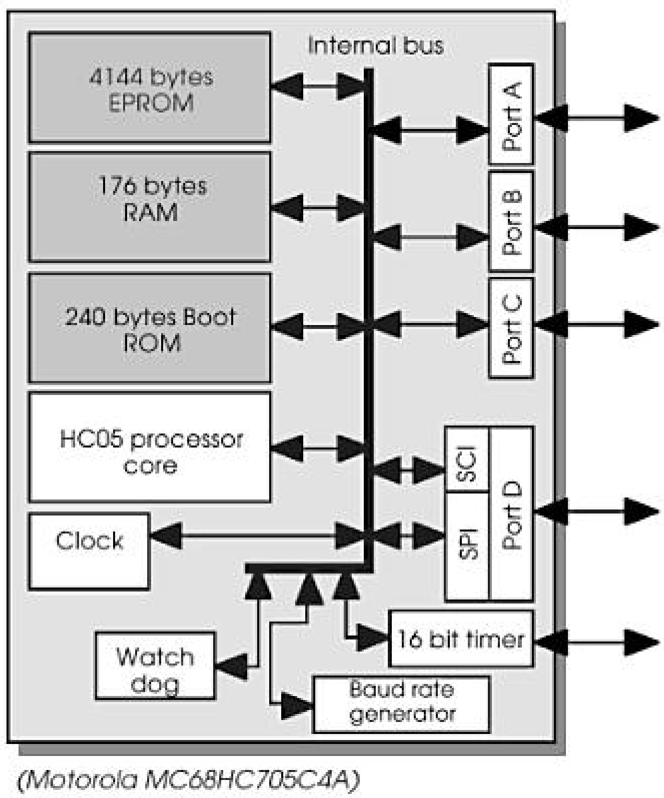


Figure 2.0

2.2 Type of controller

2.2.1 PIC Controller

PIC is a family of Harvard architecture microcontrollers made by Microchip Technology, derived from the PIC1640[7] originally developed by General Instrument's Microelectronics Division. The name PIC initially referred to "**Peripheral Interface Controller**".[8][9]

PICs are popular with both industrial developers and hobbyists alike due to their low cost, wide availability, large user base, extensive collection of application notes, availability of low cost or free development tools, and serial programming (and re-programming with flash memory) capability.

2.2.2 Digital signal processing (DSP)

Digital signal processing (**DSP**) is concerned with the representation of the signals by a sequence of numbers or symbols and the processing of these signals. Digital signal processing and analog signal processing are subfields of signal processing. DSP includes subfields like: audio and speech signal processing, sonar and radar signal processing, sensor array processing, spectral estimation, statistical signal processing, digital image processing, signal processing for communications, biomedical signal processing, seismic data processing, etc.

Since the goal of DSP is usually to measure or filter continuous real-world analog signals, the first step is usually to convert the signal from an analog to a digital form, by using an analog to digital converter. Often, the required output signal is another analog output signal, which requires a digital to analog converter.

DSP algorithms have long been run on standard computers, on specialized processors called digital signal processors (DSPs), or on purpose-built hardware such as application-specific integrated circuit (ASICs). Today there are additional technologies used for digital signal processing including more powerful general purpose microprocessors, field-programmable gate arrays (FPGAs), digital signal controllers (mostly for industrial apps such as motor control), and stream processors, among others.[3]

2.2.3 PID controller

The majority of control systems in the world are operated by proportional-integral-derivative (PID) controllers. Indeed, it has been reported that 98% of the control loops in the pulp and paper industries are controlled by single-input single output PI controllers [2] and that in process control applications, more than 95% of the controllers are of the PID type [4]. Similar statistics hold in the motion control and aerospace industries.

The PID controller calculation (algorithm) involves three separate parameters; the proportional, the integral and derivative values. The *proportional* value determines the reaction to the current error, the *integral* value determines the reaction based on the sum of recent errors, and the *derivative* value determines the reaction based on the rate at which the error has been changing. The weighted sum of these three actions is used to adjust the process via a control element such as the position of a control valve or the power supply of a heating element.

By tuning the three constants in the PID controller algorithm, the controller can provide control action designed for specific process requirements. The response of the controller can be described in terms of the responsiveness of the controller to an error, the degree to which the controller overshoots the setpoint and the degree of system oscillation. Note that the use of the PID algorithm for control does not guarantee optimal control of the system or system stability.

Some applications may require using only one or two modes to provide the appropriate system control. This is achieved by setting the gain of undesired control outputs to zero. A PID controller will be called a PI, PD, P or I controller in the absence of the respective control actions. PI controllers are particularly common, since derivative action is very sensitive to measurement noise, and the absence of an integral value may prevent the system from reaching its target value due to the control action.[5]

2.3 PID controller theory

The PID control scheme is named after its three correcting terms, whose sum constitutes the manipulated variable (MV). Hence:

$$\mathrm{MV(t)} = P_{\mathrm{out}} + I_{\mathrm{out}} + D_{\mathrm{out}}$$

where

P_{out}, I_{out}, and D_{out} are the contributions to the output from the PID controller from each of the three terms, as defined below.

2.3.1 Proportional term

The proportional term (sometimes called *gain*) makes a change to the output that is proportional to the current error value. The proportional response can be adjusted by multiplying the error by a constant K_p, called the proportional gain.

The proportional term is given by:

$$P_{\mathrm{out}} = K_p\, e(t)$$

where

P_{out}: Proportional term of output

K_p: Proportional gain, a tuning parameter

e: Error = $SP - PV$

t: Time or instantaneous time (the present)

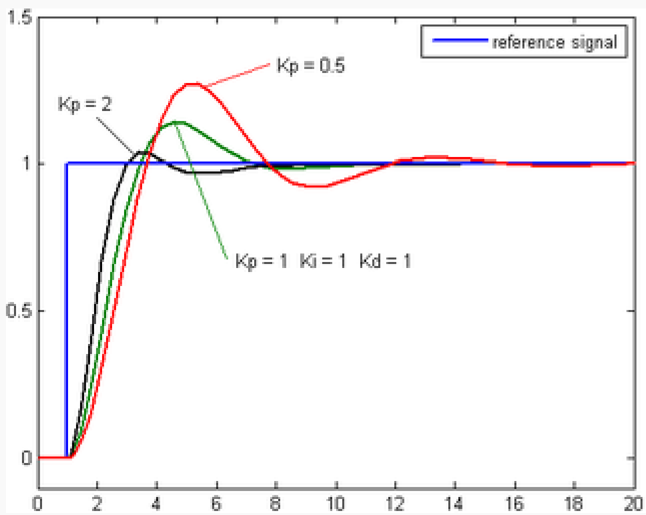


Figure 2.1.1 : Plot of PV vs time, for three values of K_p (K_i and K_d held constant)

A high proportional gain results in a large change in the output for a given change in the error. If the proportional gain is too high, the system can become unstable (See the section on loop tuning). In contrast, a small gain results in a small output response to a large input error, and a less responsive (or sensitive) controller. If the proportional gain is too low, the control action may be too small when responding to system disturbances.

In the absence of disturbances, pure proportional control will not settle at its target value, but will retain a steady state error that is a function of the proportional gain and the process gain. Despite the steady-state offset, both tuning theory and industrial practice indicate that it is the proportional term that should contribute the bulk of the output change.

2.3.2 Integral term

The contribution from the integral term (sometimes called *reset*) is proportional to both the magnitude of the error and the duration of the error. Summing the instantaneous error over time (integrating the error) gives the accumulated offset that should have been corrected previously. The accumulated error is then multiplied by the integral gain and added to the controller output. The magnitude of the contribution of the integral term to the overall control action is determined by the integral gain, K_i.

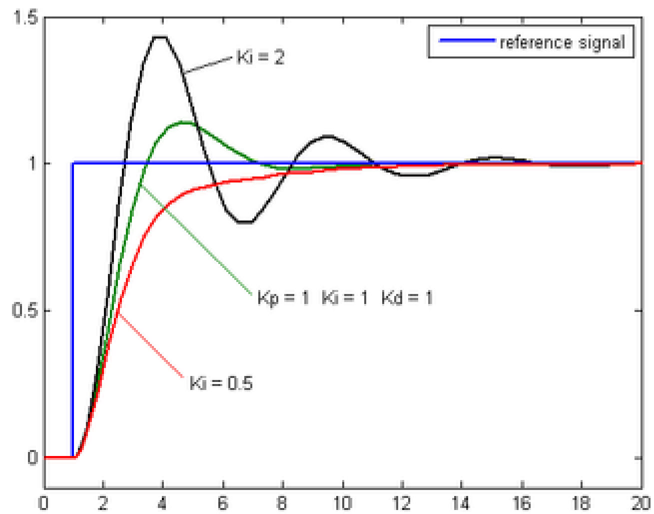


Figure 2.1.2 : Plot of PV vs time, for three values of K_i (K_p and K_d held constant)

The integral term is given by:

$$I_{\text{out}} = K_i \int_0^t e(\tau)\,d\tau$$

where

I_{out}: Integral term of output

K_i: Integral gain, a tuning parameter

e: Error = $SP - PV$

t: Time or instantaneous time (the present)

τ: a dummy integration variable

The integral term (when added to the proportional term) accelerates the movement of the process towards setpoint and eliminates the residual steady-state error that occurs with a proportional only controller. However, since the integral term is responding to accumulated errors from the past, it can cause the present value to overshoot the setpoint value (cross over the setpoint and then create a deviation in the other direction). For further notes regarding integral gain tuning and controller stability, see the section on loop tuning.

2.3.3 Derivative term

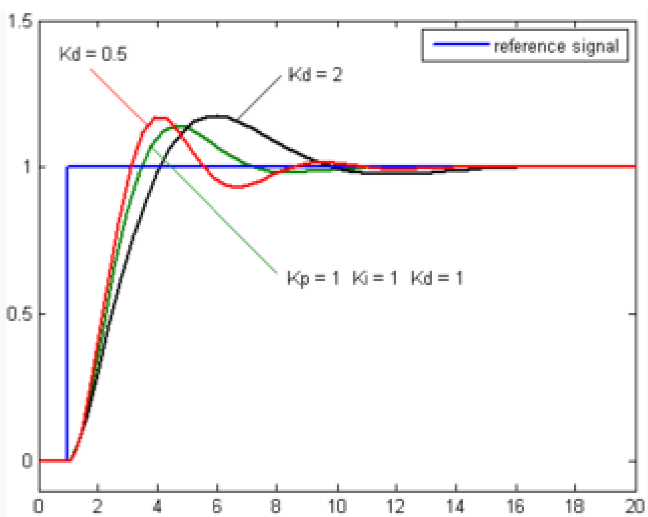


Figure 2.1.3 : Plot of PV vs time, for three values of K_d (K_p and K_i held constant)

The rate of change of the process error is calculated by determining the slope of the error over time (i.e., its first derivative with respect to time) and multiplying this rate of change by the derivative gain K_d. The magnitude of the contribution of the derivative term (sometimes called *rate*) to the overall control action is termed the derivative gain, K_d.

The derivative term is given by:

$$D_{\mathrm{out}} = K_d \frac{d}{dt} e(t)$$

where

D_{out}: Derivative term of output

K_d: Derivative gain, a tuning parameter

e: Error = $SP - PV$

t: Time or instantaneous time (the present)

The derivative term slows the rate of change of the controller output and this effect is most noticeable close to the controller setpoint. Hence, derivative control is used to reduce the magnitude of the overshoot produced by the integral component and improve the combined controller-process stability. However, differentiation of a signal amplifies noise and thus this term in the controller is highly sensitive to noise in the error term, and can cause a process to become unstable if the noise and the derivative gain are sufficiently large.

2.4 PWM (pulse width modulation)

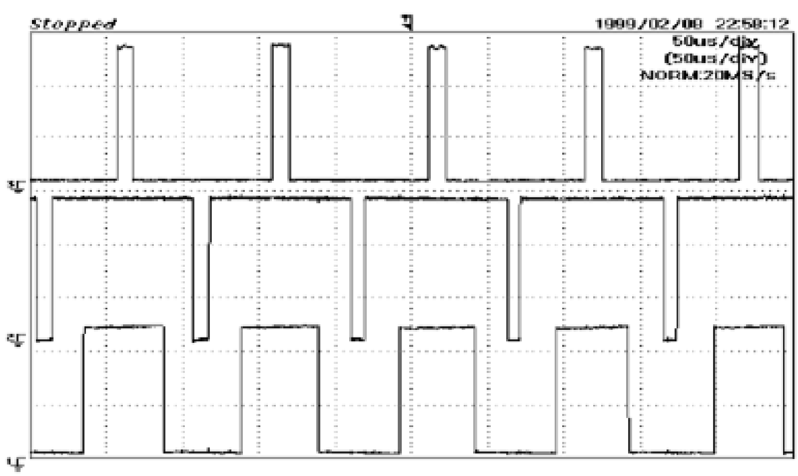
2.4.1 General definitions of PWM

Pulse-width modulation (PWM) is a very efficient way of providing intermediate amounts of electrical power between fully on and fully off. A simple power switch with a typical power source provides full power only, when switched on. PWM is a comparatively-recent technique, made practical by modern electronic power switches. The term **duty cycle** describes the proportion of **on** time to the regular interval or **period** of time; a low duty cycle corresponds to low power, because the power is off for most of the time. Duty cycle is expressed in percent, 100% being fully on. PWM works well with digital controls, which, because of their on/off nature, can easily set the needed duty cycle.[10]

2.4.2 Application of PWM

One of PWM application is to control switching of power transistor in power inverter. This application most used in controlling speed of induction motor. The microcontroller produced PWM signal that programmed by user and it will be sent to the inverter. The pulse of the PWM signal give high and low signal to on and off the power transistor switching. Higher the frequency of the PWM signal, faster the switching is. The switching of power transistor then control the induction motor.[10]

2.4.3 Example of different time-scale of PWM



Three-phase PWM signals at different time-scale

Figure 2.2

CHAPTER 3

METHODOLOGY

3.0 Introduction

This chapter will discuss on the methods that will be used to ensure the project could achieve the objective and scope of the project. Thus, all the methods need to be done as in schedule so that this project could be completed within time. The relevant information is gathered and discussed through literature review. There are several steps to be applied in designing a three phase induction motor controller. First of all, the theory about three phase induction motor control methods are discussed with details according to the literature review. Secondly the hardware development parts are explained with details about their function and operation. The final part is to develop PCB board using DXP 2004.

The whole idea of this project can be finalize as the block diagram showed in figure below. The block diagram show general preview about the controller side that will be interfaced with power inverter side.

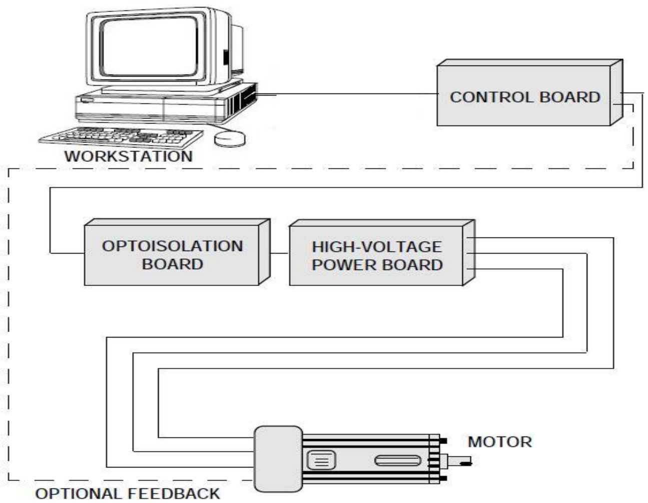


Figure 3.0 : system block diagram

3.1 System block diagram

Figure 3.0 shows the system block diagram of the induction motor control system. When an induction motor start, it run in a constant torque called base torque. Then, when there are changes occur in the load, this system need to maintain the torque. So that the current and voltage will drop due to the changes in the load. This current and voltage drop signals are then send to the microcontroller by fault circuit. The microcontroller compares reference voltage and varies to control the frequency to maintain the torque. The microcontroller using PID controller and produce six controlled PWM output that send to a driver circuit and control 6 switches in the power inverter. Three PWM output are required to control the upper three switches of the power inverter. The lower switches are controlled by the inverted PWM signals of the corresponding upper switch. A dead time is given between switching off the upper switch and switching on the lower switch and vice versa, to avoid shorting the DC bus. This process makes the frequency of the motor verified. This method is called V/f control method.

3.2 Control board

Control board is main board that consists of processor port, power driver I/O connector to connect with high voltage power board part. It also designs with variable speed using potentiometer and start/stop also forward/reverse switch. Control board shown in appendix consists of following parts:

3.3 Daughter Board Circuit

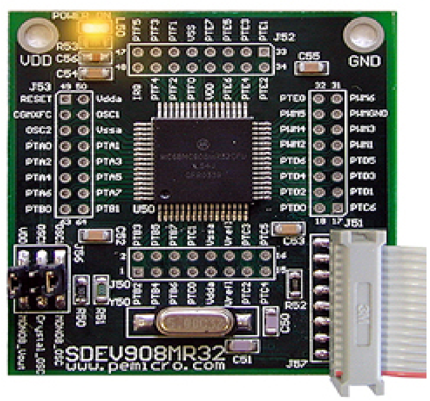
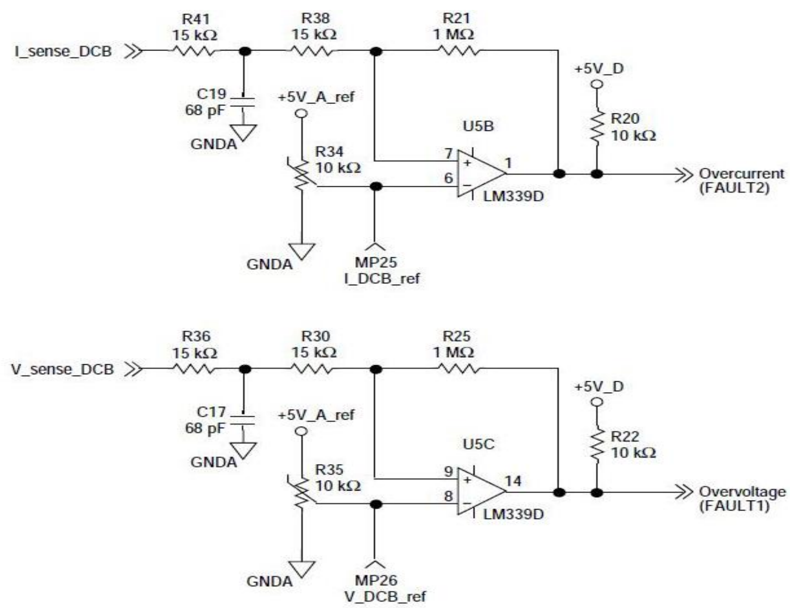


Figure 3.1

The daughter board that used in control board is a MC68HC908MR32 microcontroller is attached on control board using connector port and it is designed separately from control board for safety and troubleshooting purposes.

3.4 Fault circuit

The fault circuit in figure below is sensed two fault signals that generated from the analog bus current and bus voltage feedback signals. This over voltage and over current signals then fed into comparators that have adjustable reference voltage. The comparator output then provide digital signal to the microchip input. This fault input will force the PWM module into a known inactive state, protecting the power stage output.



Fault Circuits

Figure 3.2

3.5 Tachometer circuit

One of the methods for measuring motor speed is to use the analog ac output signal from a tachometer connected to the motor's shaft. The conditioned signal then can be carried into a timer interrupt on the MR32. The period between interrupts is used to calculate motor shaft speed.

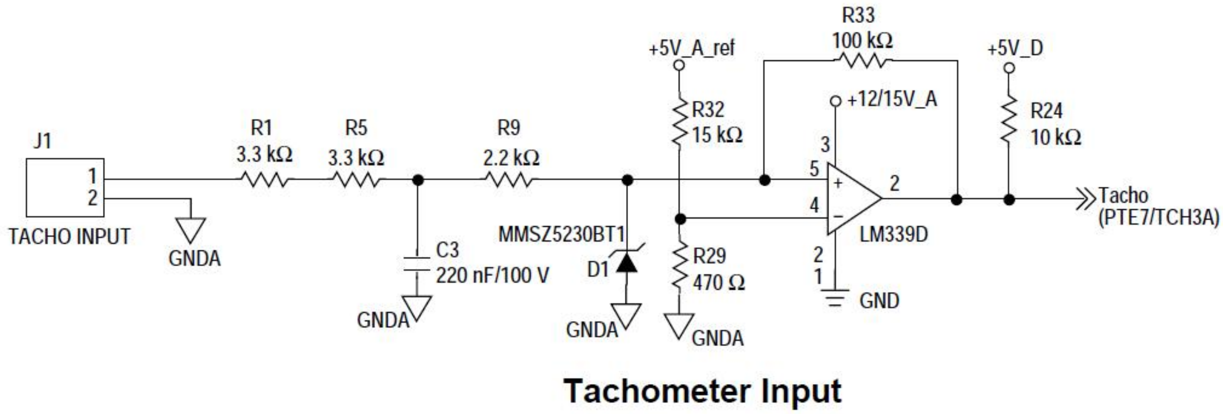


Figure 3.3 : Tachometer circuit

3.6 Optoisolated circuit

Optoisolated circuit is designed for safety purpose and is suitable for communication rates up to 9600 baud. It's used to separate high voltage and low voltage

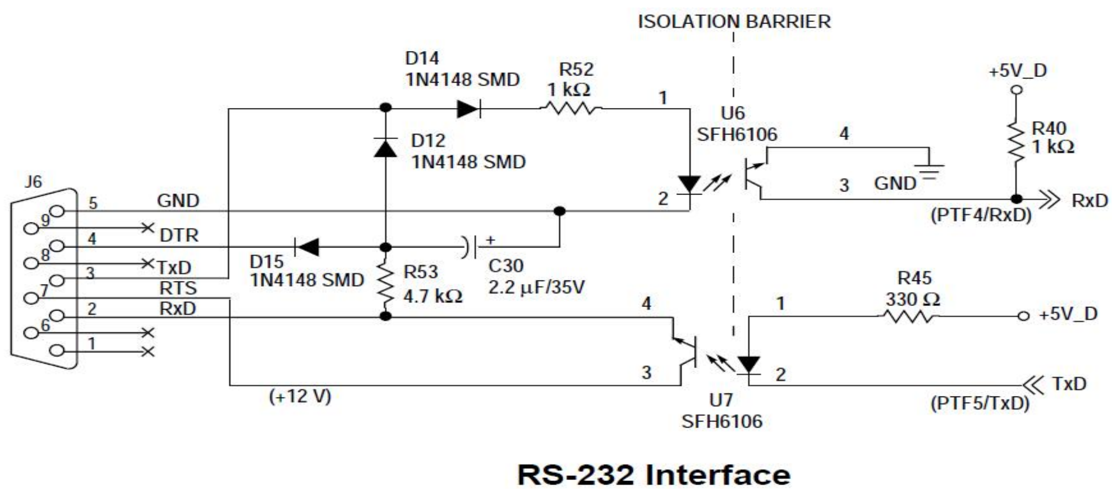


Figure 3.4 : RS-232 Interface

3.7 Control board block diagram

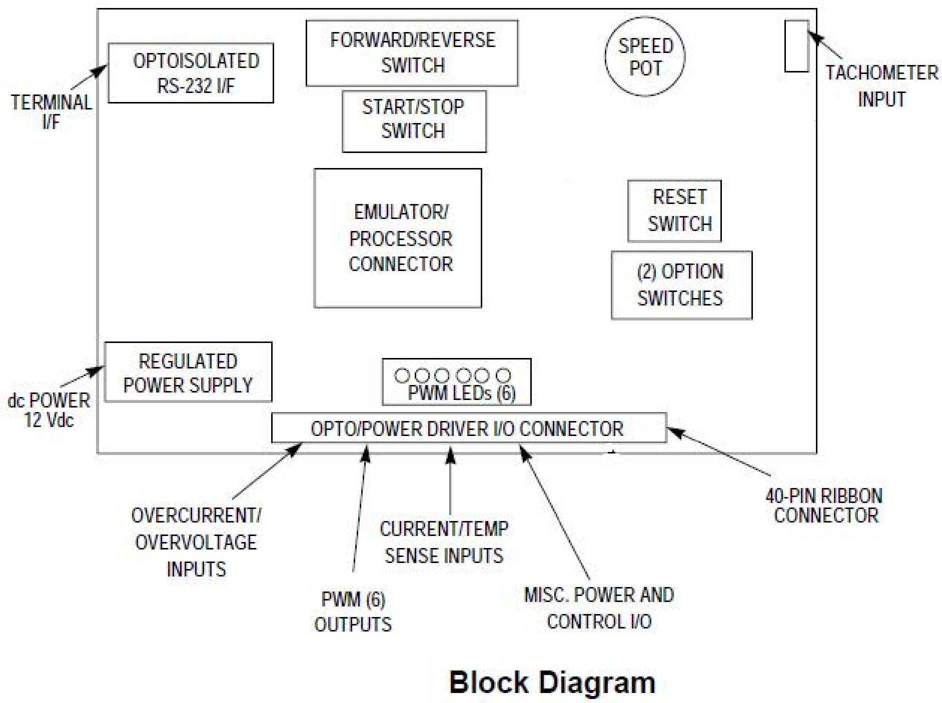


Figure 3.5: Block diagram of control board

3.8 Pulse-width modulator for motor control (PWMMC)

The PWM module can generate three complementary PWM pairs or six independent PWM signals. These PWM signals can be center-aligned or edge-aligned.

A12-bit timer PWM counter is common to all six channels. PWM resolution is one clock period for edge-aligned operation and two clock periods for center-aligned operation. The clock period is dependent on the internal operating frequency (fOP) and a programmable prescaler. The highest resolution for edge-aligned operation is 125 ns (fOP = 8 MHz). The highest resolution for center-aligned operation is 250 ns (fOP= 8 MHz).

When generating complementary PWM signals, the module features automatic dead-time insertion to the PWM output pairs and transparent toggling of PWM data based upon sensed motor phase current polarity. Features of the PWMMC include:

• Three complementary PWM pairs or six independent PWM signals
• Edge-aligned PWM signals or center-aligned PWM signals
• PWM signal polarity control
• 20-mA current sink capability on PWM pins
• Manual PWM output control through software
• Programmable fault protection
• Complementary mode featuring:
  - Dead-time insertion
  - Separate top/bottom pulse width correction via current sensing or programmable software bits

3.9 Selecting six independent pwms or three complementary PWM pairs

The PWM outputs can be configured as six independent PWM channels or three complementary channel pairs. If complementary operation is chosen, the PWM pins are paired as shown in Figure 7. Operation of one pair is then determined by one PWM value register.

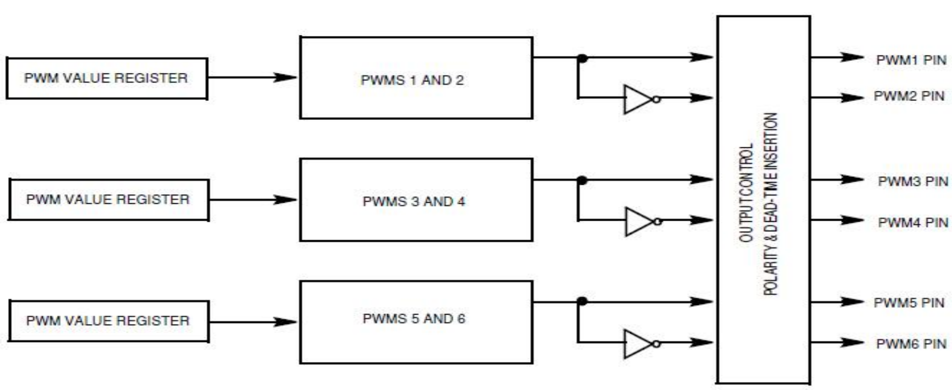


Figure 3.6: Complementary Pairing

3.10 SIMULATION

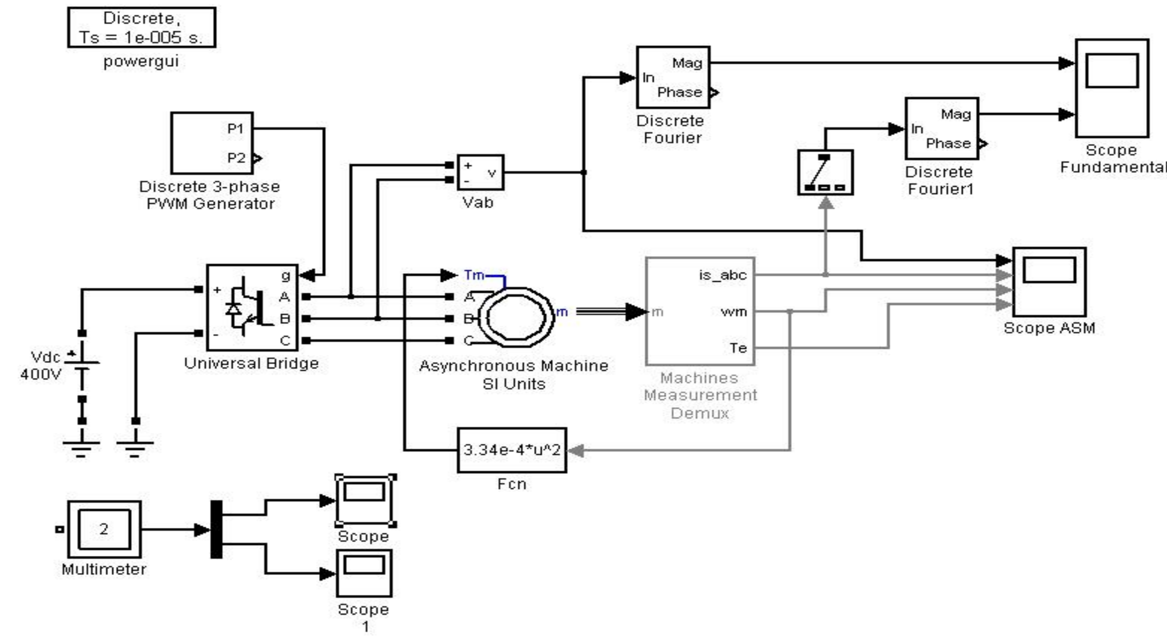


Figure 3.7

The Figure 3.7 shows the Matlab block diagram of PWM control of an induction motor.

3.10.1 Assembling and Configuring the simulation block

First, all block is setup as in figure 3.7. then the parameter of motor used is set up in the motor block dialog box. Then, the parameter for PWM generator block is set up. The ASM scope that connected will display the waveform of line voltage, line current, motor speed and torque.

3.11 Printed Circuit Board (PCB) Design

In designing the printed circuit board layout, software tool is called DXP 2004 was used. Starting from drawing circuit diagram until routing process is done automatically by this software. If there are problem, we can also do it manually. There are several steps to do it. First, the schematic of the circuit is drown using DXP software as in figure 3.8. Then the schematic circuit is exported to PCB layout design and the component footprint is rearranged in order as figure 3.9. Then rule is setup for circuit routing. The width of the root, the clearance between the root and the hole size is set up. After that, the circuit connection is rout automatically as in figure 3.10 and polygon plan is created as show in figure 3.11.

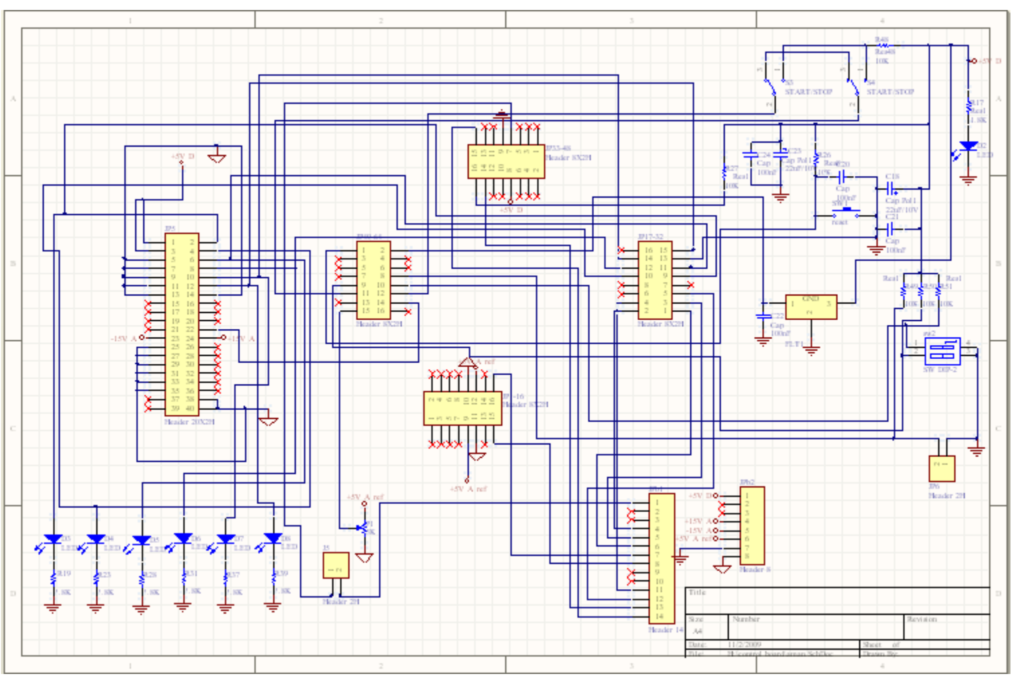


Figure 3.8: Drawing schematic

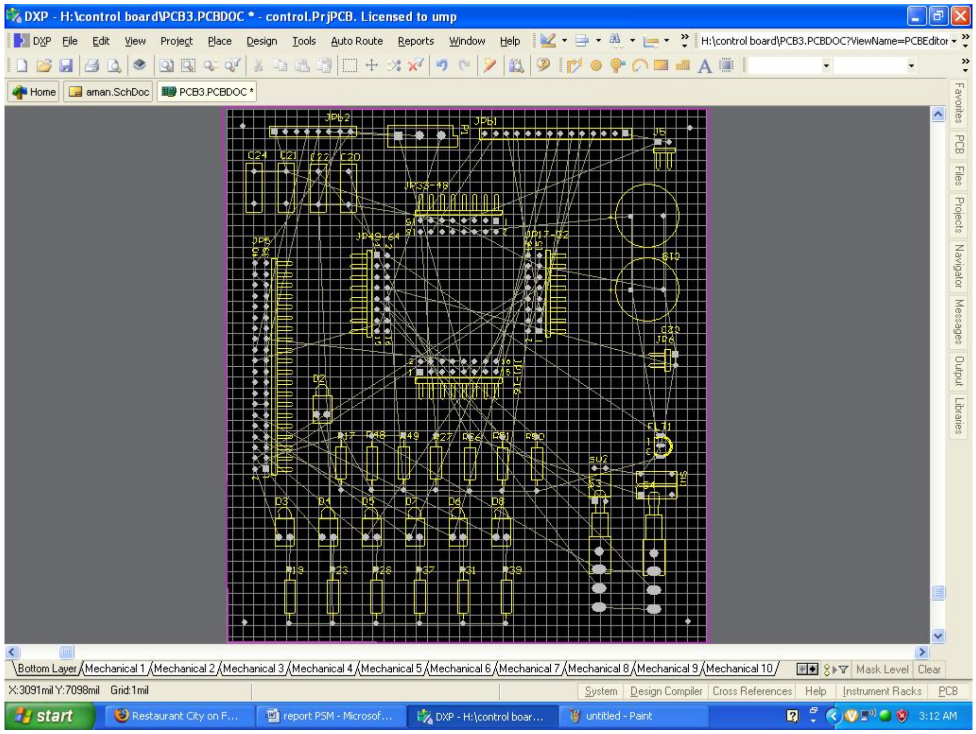


Figure 3.9: Export schematic to PCB layout

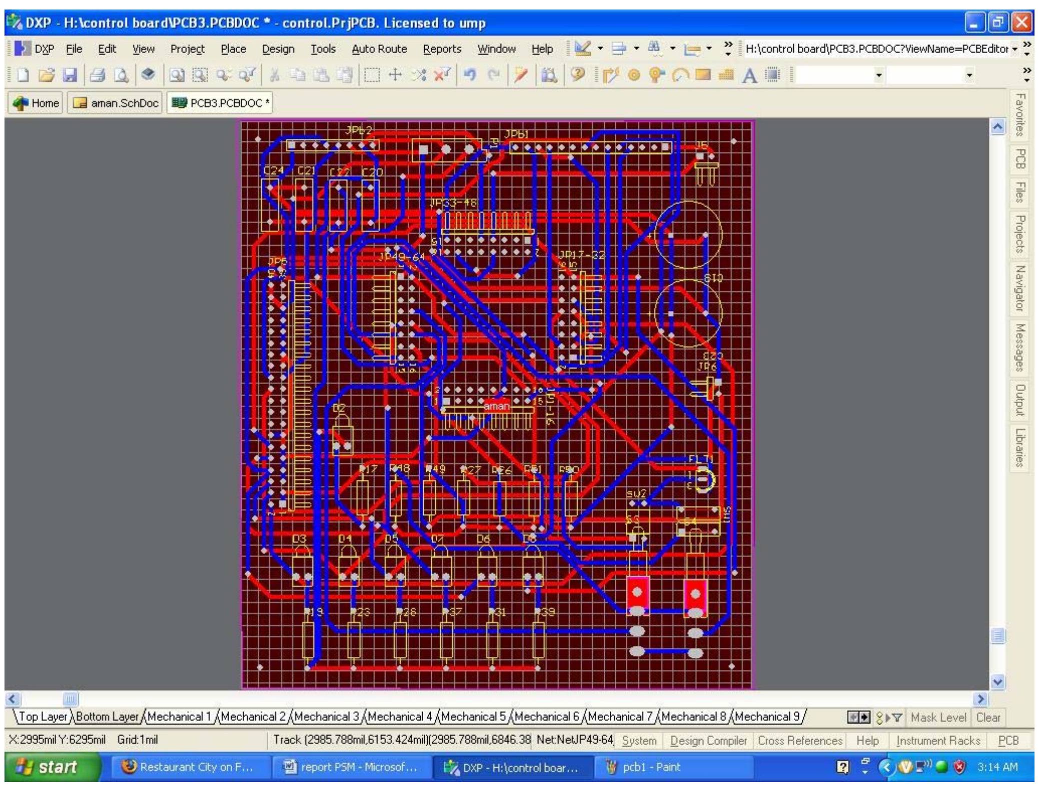
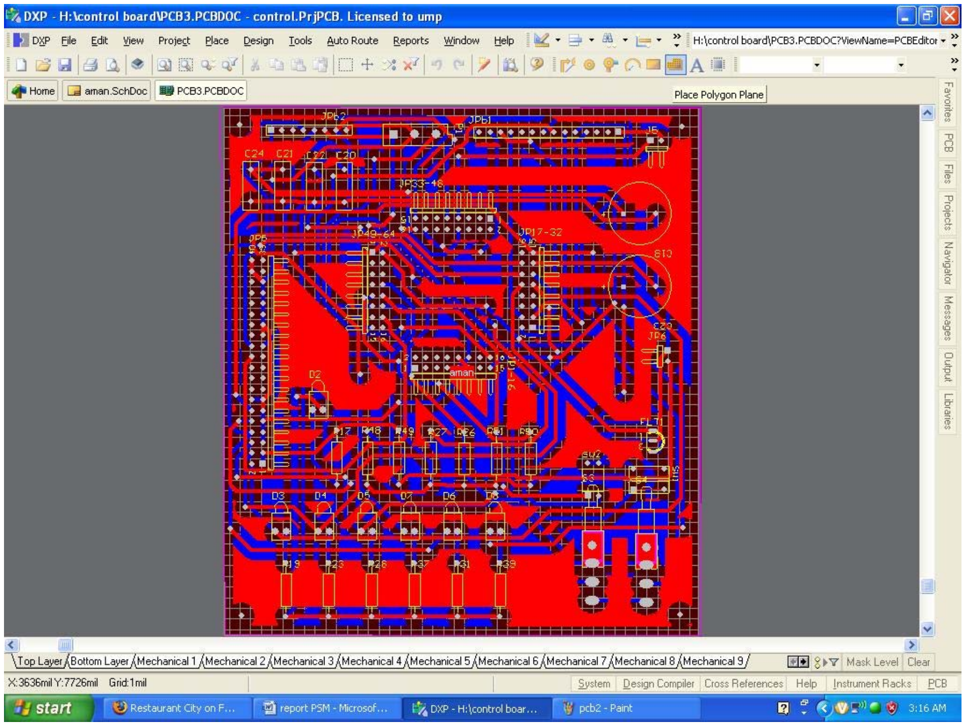


Figure 3.10: PCB routing for first board



3.11 : Place polygon plane

3.12 Generating Gerber files

Finally, after finished the designing PCB layout it need the files format to transfer it to the applicable machine for making the PCB board. This files format is called Gerber file and NC drill file. A Gerber File is a file format used by printed circuit board manufacturing machines to layout electrical connections such as traces, vias, and pads (the component "footprints" on the PCB). In addition, the file contains information for drilling, and milling the completed circuit board. These files are generated by PCB layout software (DXP 2004), and are sent to manufacturing companies where they are uploaded to the applicable machines for each step of the PCB production process.

Each Gerber file corresponds to one layer in the physical board that consists of the component overlay, top signal layer, bottom signal layer, the solder masking layers and so on.

It is advisable to consult with your PCB manufacturer to confirm their requirements before generating the Gerber and NC drill files required to fabricate your design. The gerber file is shown in figure 3.12

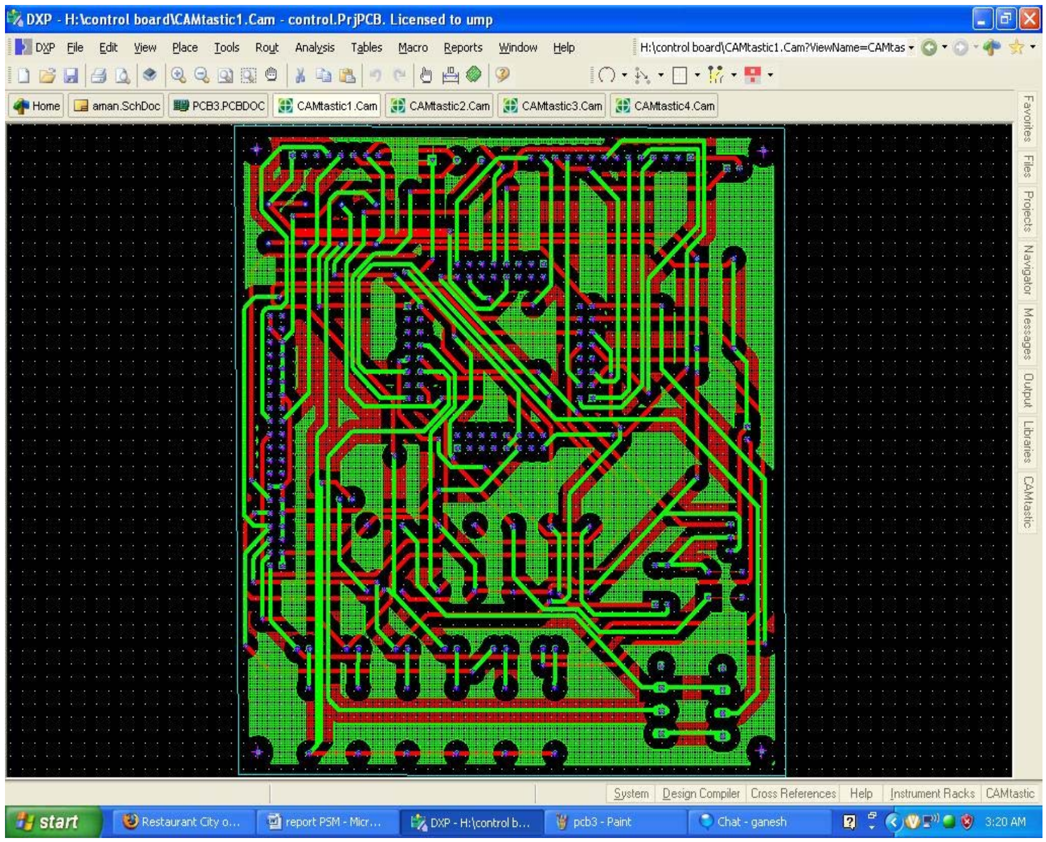


Figure 3. 12 : Gerber file

Figure 3.13 and Figure 3.14 show the final layout of the PCB board design

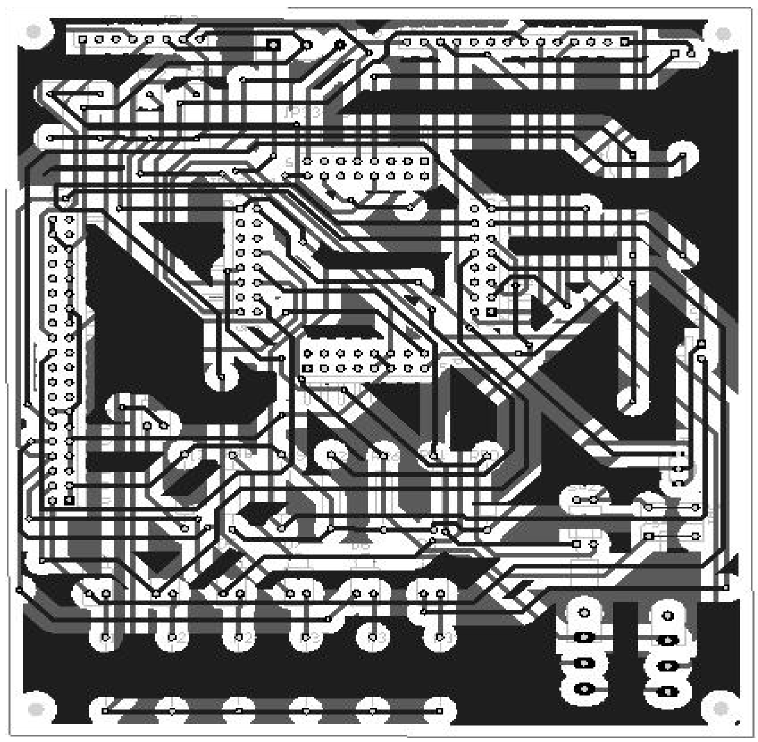


Figure 3.13: finished board 1

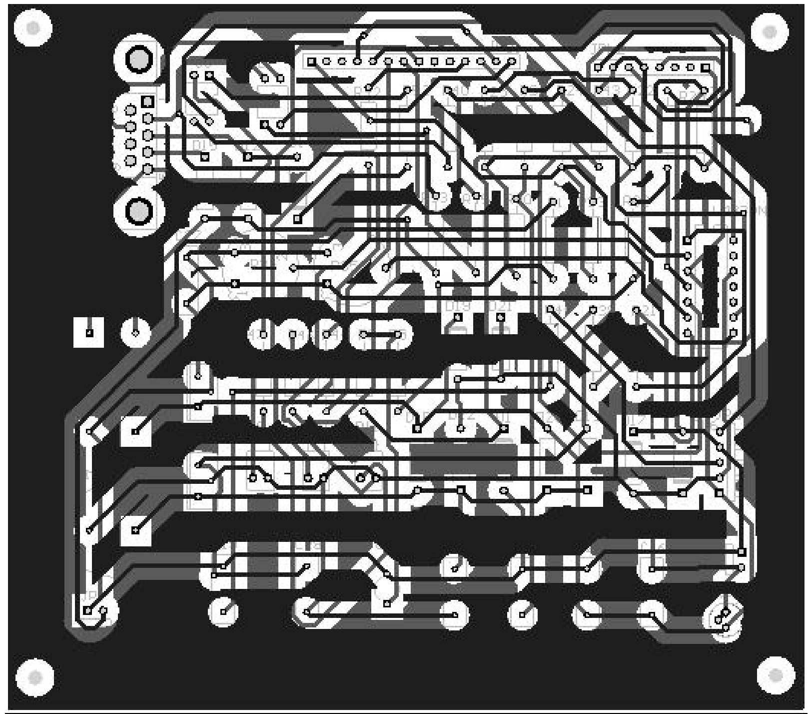


Figure 3.14: finished board 2

CHAPTER 4

RESULT AND DISCUSSION

4.0 Introduction

This chapter described and discussed of experimental and simulation result related to the 3 phase induction motor controller. The power inverter board will receive PWM signal and vary the motor speed.

This chapter is divided into three parts:

i. Design the control board using the printed circuit board(PCB)
ii. Simulation of controlled PWM induction motor controller system by using Matlab
iii. Hardware implementation result.

4.1 Printed Circuit Board

The printed circuit board (PCB) were designed using the Protel 2004 software and this method were choose instead of using the wire board because of its advantage for us to troubleshoot the hardware, easy to solder and we can design compact circuit or hardware. Furthermore, this is the best software tools to create PCB board as the beginner.

The PCB boards of this project are designing in double layers. The works in designing the three phase inverter using the printed circuit board are divided into three parts. The first part is to draw it schematic design using the software and the entire component needed in designing it were available in the Protel 2004 library. The integrated library is needed to create because these boards require another type of footprint. For example, the pin for daughter board socket need to be measure and placed correctly in order to fit it successfully.

After finished the designing the schematic layout (figure 4.0) and (figure 4.1), the next step is compiling the schematic design and making the printed circuit board layout. This layout will be design whether we want to use a double layer board or single layer board. The third part is to route the board connection according to layout design. The PCB layout is showed in the figure and figure 4.2 and figure 4.3.

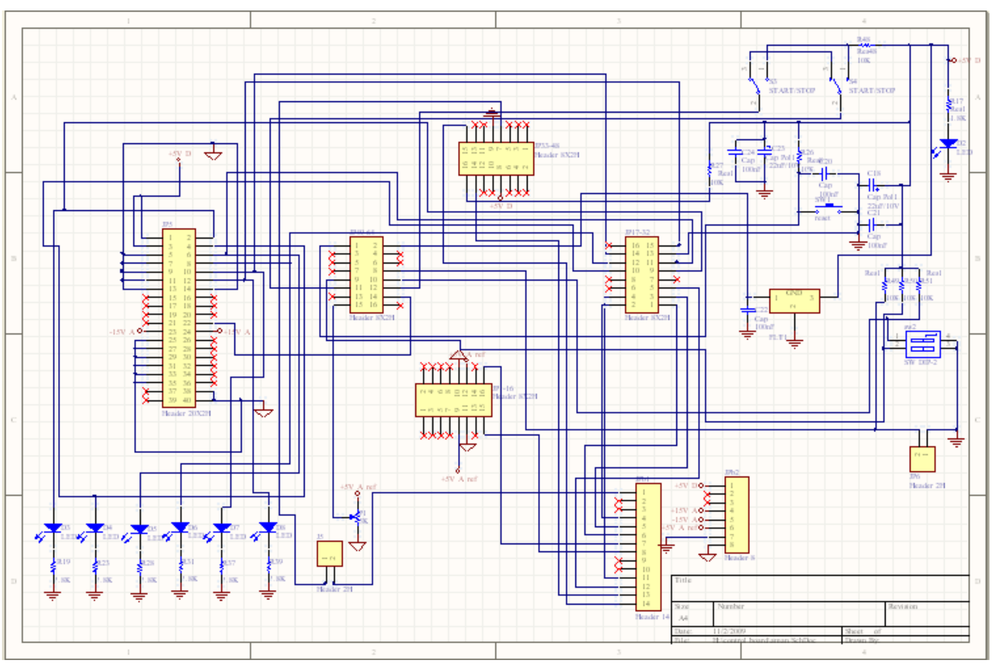


Figure 4.0

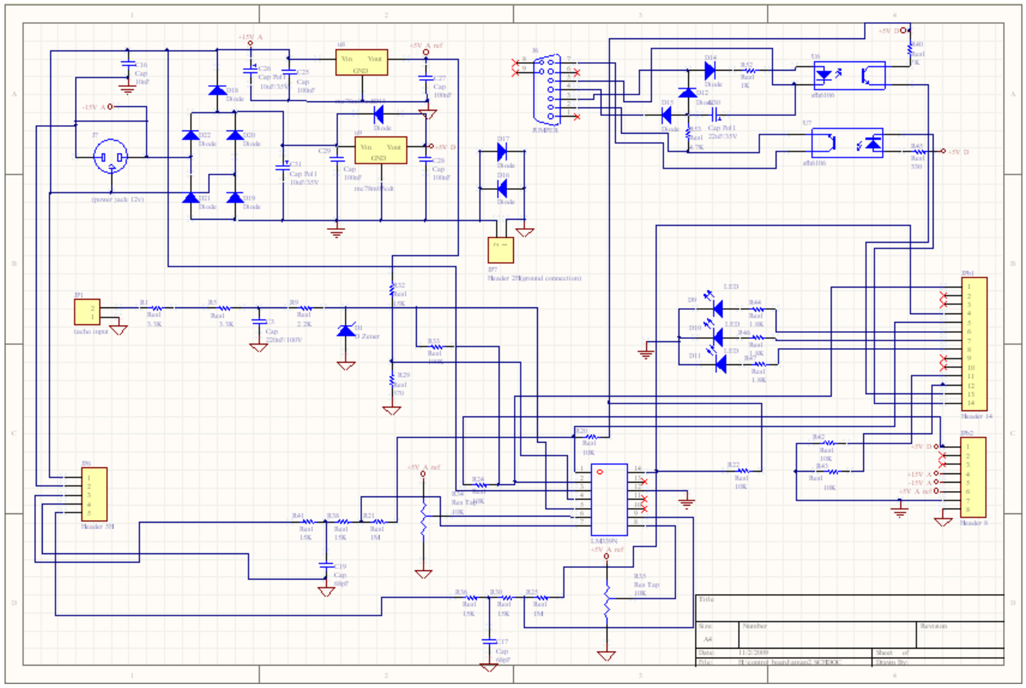


Figure 4.1

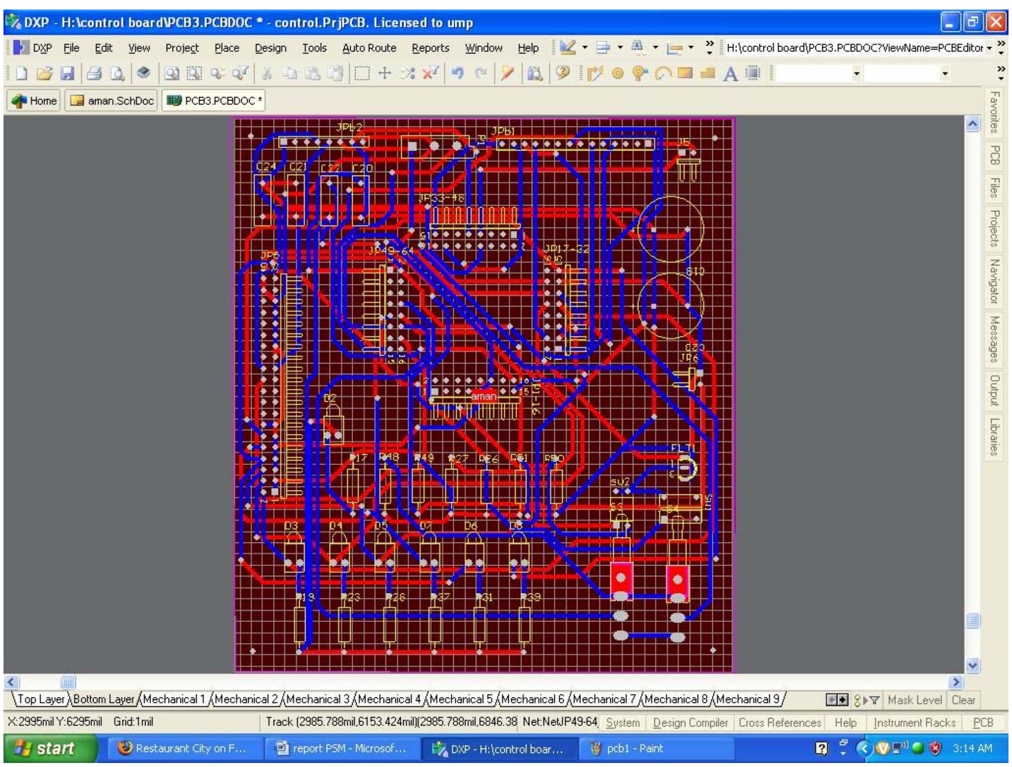


Figure 4.2

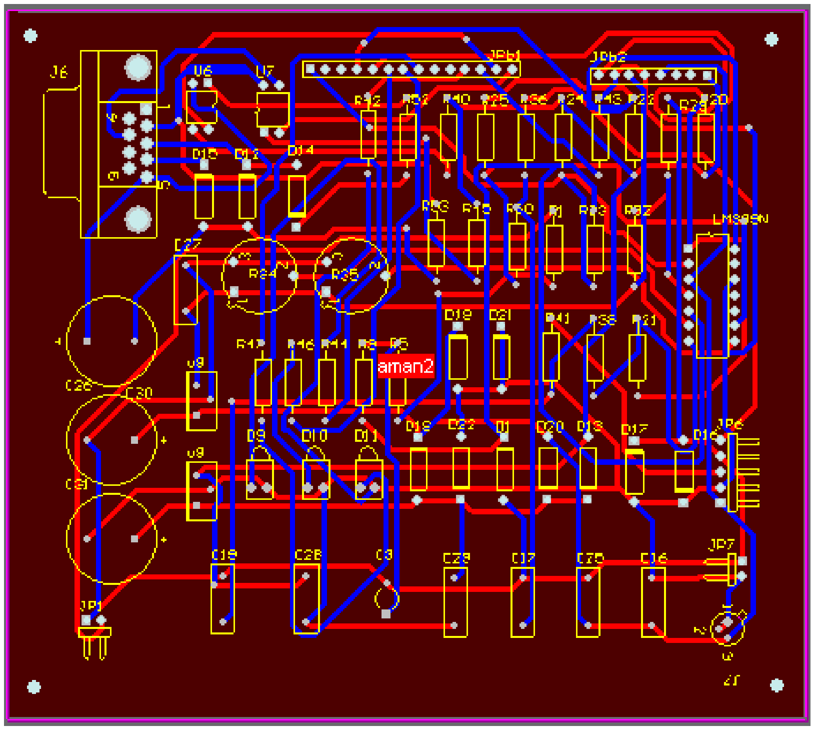


Figure 4.3

Figure 4.4, 4.5, and 4.6 shows the finished PCB board that designed using DXP 2004 software.

Figure 4.4 : first board

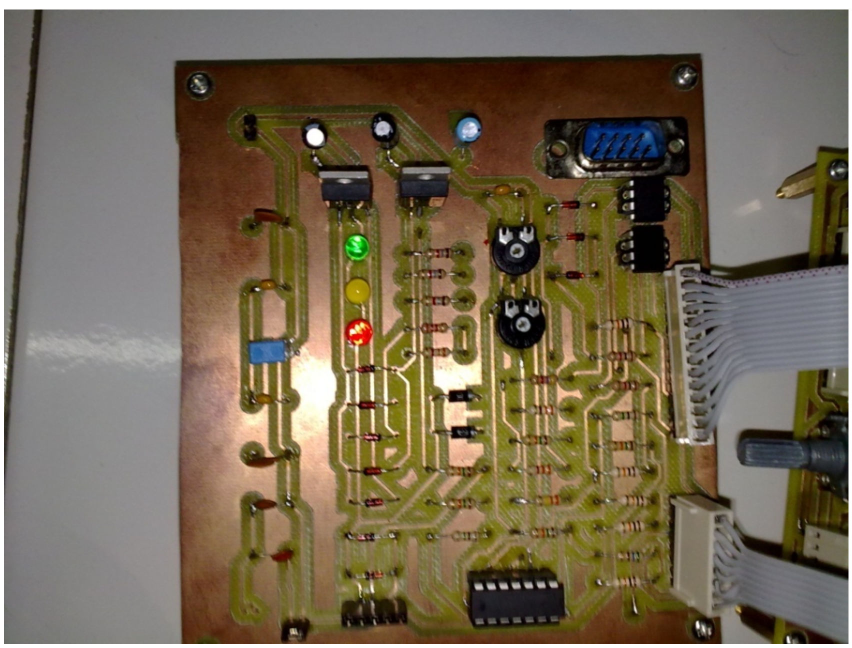


Figure 4.5 : second board

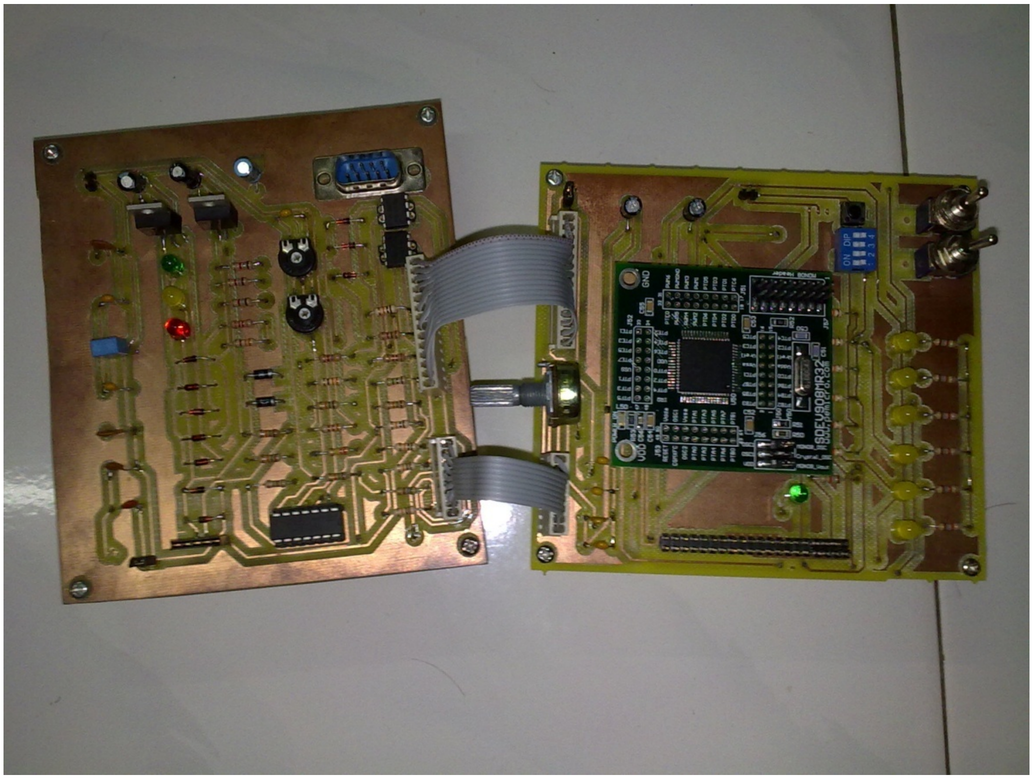


Figure 4.6 : both connected circuit

4.2 Matlab Simulation

The simulation of the three phase induction motor controller system had been done by using the Matlab software. This simulation is to view in theory concept of the waveform results for the system designed.

4.2.1 System block diagram

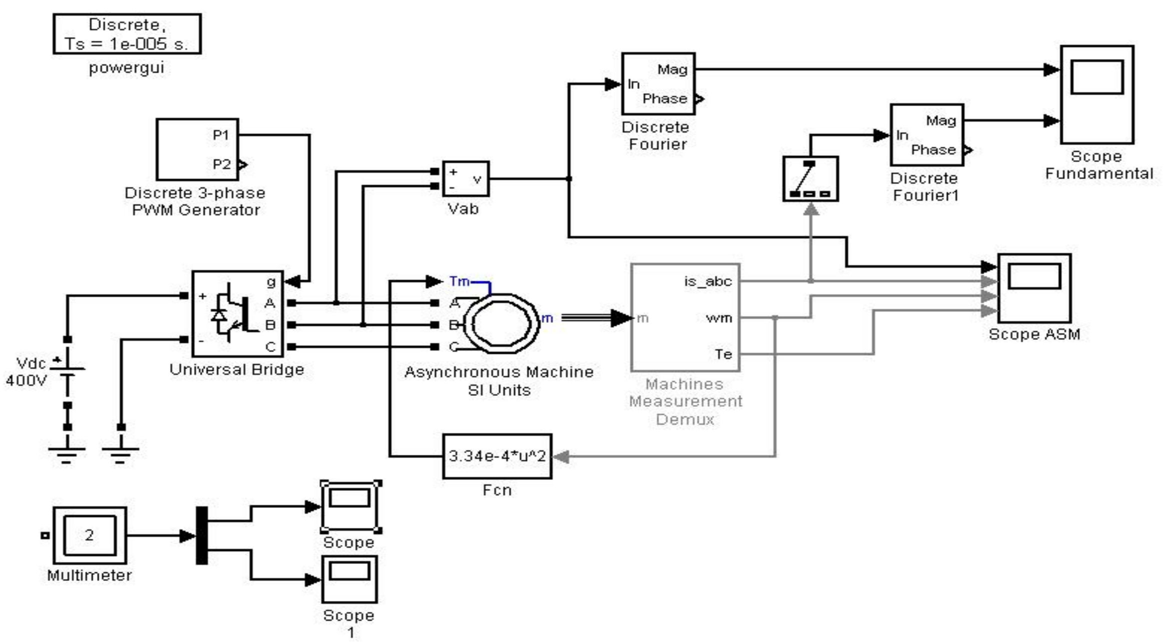


Figure 4.7

The Figure 4.7 shows the Matlab block diagram of PWM control of an induction motor. The Figure 4.8 shows the simulation results for motor starting at full voltage. From the results, we can get four graphs. First graph is the voltage, second graph is for stator current, third graph is for rotor speed of the motor and the fourth graph is for electromagnetic torque.

The simplest method normally used is direct on line to starting induction motor. By using direct on line and without using any controller, the motor switched on directly to full supply voltage and initial starting current is large, normally about 5 to 7 times the rated current but the starting torque is likely to be 0.75 to 2 times the full load torque. There is transient stage before reach the constant speed.

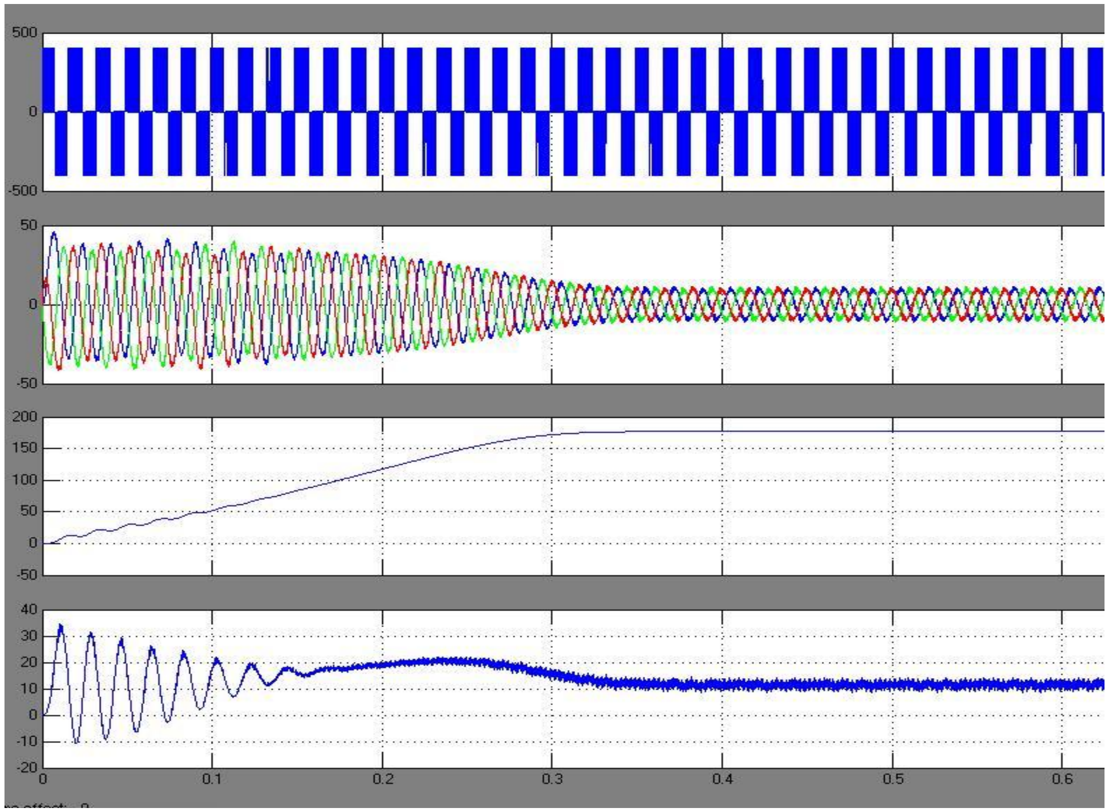


Figure 4.8

As well as this design of three phase induction motor controller, it eliminates the high initial starting current and torque. So that, as we can see in third graph, when motor starting the graph increase slowly and maintain the constant rotor speed.

Variable speed control of AC electrical machines makes use of forced-commutated electronic switches such as IGBTs, MOSFETs, and GTOs. Asynchronous machines fed by pulse width modulation (PWM) voltage sourced converters (VSC) are nowadays gradually replacing the DC motors and thyristor bridges.

With PWM, combined with modern control techniques such as field-oriented control or direct torque control, can obtain the same flexibility in speed and torque control as with DC machines. This section shows how to build a simple open loop AC drive controlling an asynchronous machine.

CHAPTER 5

CONCLUSION AND FUTURE WORK

5.0 Conclusion

At the end of this project, the result shows that speed of the three phase induction motor can be control by varying voltage and frequency of the input signal and by controlling the switching of the power transistor.

5.1 Future Works and Recommendations

After finishing the work, the author would like to forward some suggestion to improve the efficient of the induction motor controller as the future work of this project;

1. In this project, I use PID controller and V/F control method. In the future, we also can use other type of controller and different method to control the speed of three phase induction motor

2. In future, can add more function and safety application to the controller or system to assure that any fault did not damage the hardware and the system can be use for multifunction or all type of motor.

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[10] "GENERATION OF PULSE WIDTH MODULATION (PWM) SIGNALS FOR THREE- PHASE INVERTER USING A SINGLECHIP MICROCONTROLLER"

ZAINAL SALAM1 & KHOSRU MOHAMMAD SALIM

Jurnal Teknologi, 34(D) Jun 2001: 1–12

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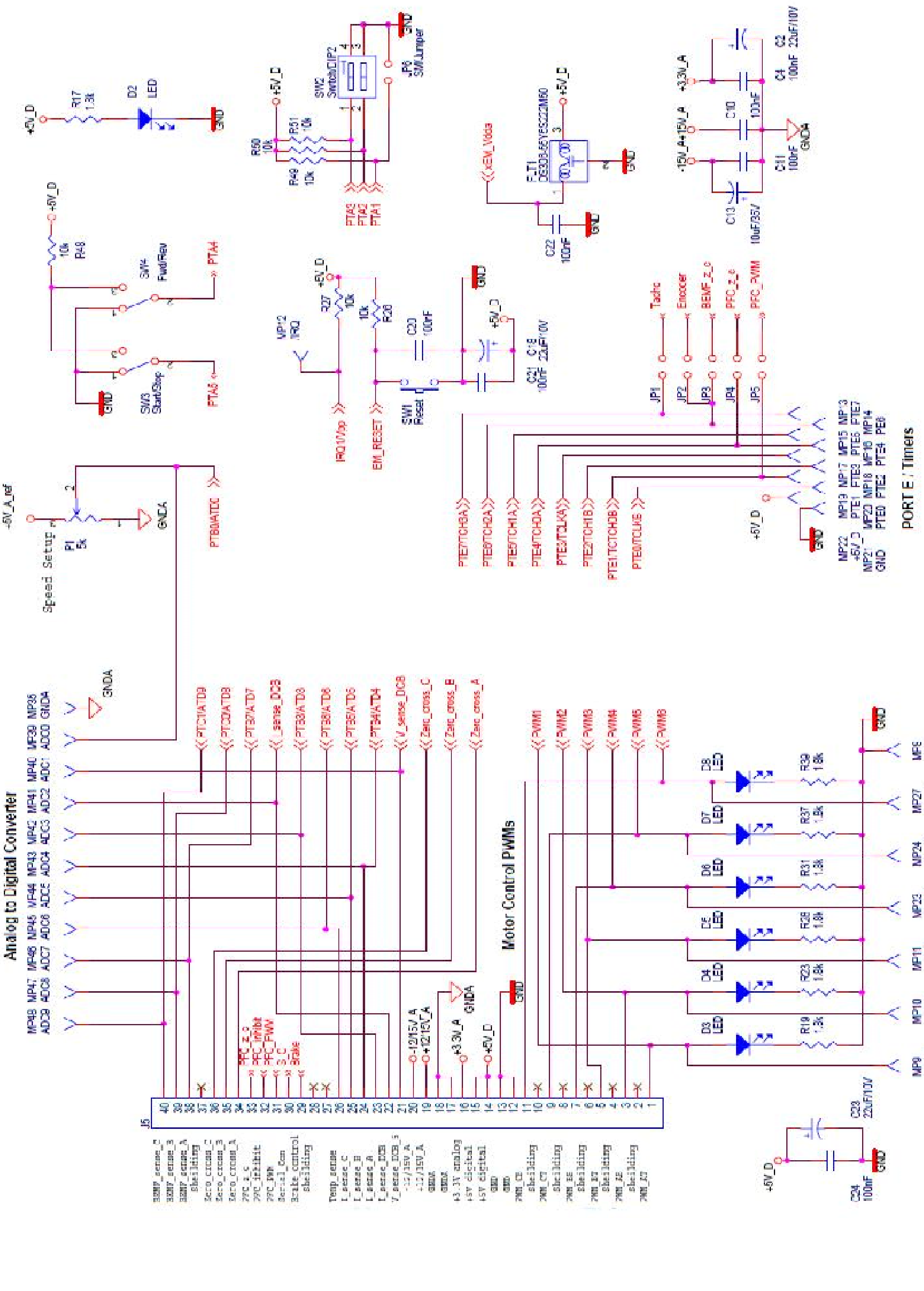
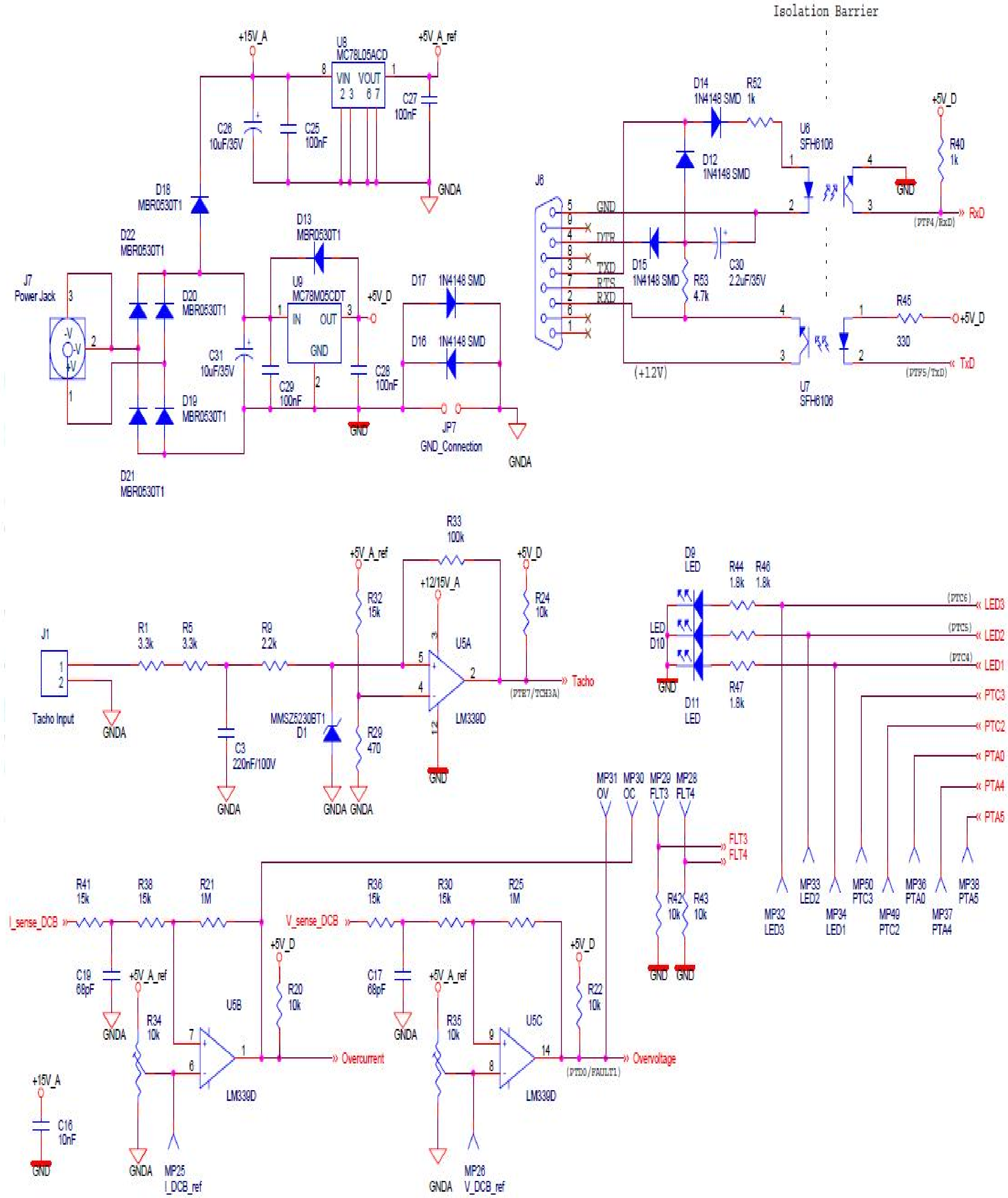
APPENDIX


Analog to Digital Converter
Motor Control PWMs
PORT E / Timers



Isolation Barrier
+15V_A
U8
MC78L05ACD
VIN
VOUT
+5V_A_ref
C27
100nF
C26
10uF/35V
C25
100nF
GNDA
D18
MBR0530T1
D22
MBR0530T1
D20
MBR0530T1
D19
MBR0530T1
D21
MBR0530T1
J7
Power Jack
D13
MBR0530T1
U9
MC78M05CDT
IN
OUT
GND
+5V_D
C31
10uF/35V
C29
100nF
C28
100nF
D17
1N4148 SMD
D16
1N4148 SMD
JP7
GND_Connection
D14
1N4148 SMD
R52
1k
D12
1N4148 SMD
U6
SFH6106
R40
1k
J6
GND
DTR
TXD
RTS
RXD
D15
1N4148 SMD
R53
4.7k
C30
2.2uF/35V
(PTF4/RxD)
RxD
R45
330
(PTF5/TxD)
TxD
(+12V)
U7
SFH6106
R33
100k
R32
15k
+12/15V_A
R24
10k
J1
Tacho Input
R1
3.3k
R5
3.3k
R9
2.2k
U5A
LM339D
(PTE7/TCH3A)
Tacho
C3
220nF/100V
MMSZ5230BT1
D1
R29
470
D9
LED
LED
D10
D11
LED
R44
1.8k
R46
1.8k
R47
1.8k
(PTC6)
LED3
(PTC5)
LED2
(PTC4)
LED1
PTC3
PTC2
PTA0
PTA4
PTA5
MP31
OV
MP30
OC
MP29
FLT3
MP28
FLT4
FLT3
FLT4
R42
10k
R43
10k
MP32
LED3
MP33
LED2
MP34
LED1
MP50
PTC3
MP49
PTC2
MP36
PTA0
MP37
PTA4
MP38
PTA5
R41
15k
R38
15k
R21
1M
I_sense_DCB
C19
68pF
R34
10k
U5B
LM339D
R20
10k
Overcurrent
MP25
I_DCB_ref
R36
15k
R30
15k
R25
1M
V_sense_DCB
C17
68pF
R35
10k
U5C
LM339D
R22
10k
(PTD0/FAULT1)
Overvoltage
MP26
V_DCB_ref
C16
10nF

FAKULTI KEJURUTERAAN ELEKTRIK & ELEKTRONIK

UNIVERSITI MALAYSIA PAHANG (UMP)

BORANG PEMBELIAN KOMPONEN/BAHAN PSM

Sila isi secara **bertaip** dalam **3** salinan dan hantar bersama **1** salinan litar projek berkaitan

Komponen yang rosak kerana kecuaian pelajar tidak boleh diganti

Nama Pelajar: **AHMAD FAKHRUZZAMAN B M ZAWAWI**		**Nama Penyelia: En. Rosmadi Abdullah**
ID No: **EC07072**	**Tajuk Projek: Design and Development Three Phase AC-Induction Motor Using V/f control Algorithm**	**PSM 1/ PSM 2** (tanda yang berkenaan)

Bil	Bahan/Komponen	Spesifikasi	Anggaran Harga / unit	Kuantiti	Anggaran Harga
1	capacitor	2.2uF/10vdc tantalum		2	
2	capacitor	22uF/10vdc tantalum		6	
3	capacitor	22onF/63vdc polyester		2	
4	capacitor	100nF/50vdc ceramic		26	
5	capacitor	470pF/50vdc ceramic		6	
6	capacitor	10nF/50vdc ceramic		8	
7	capacitor	10uF/35vdc tantalum		6	
8	capacitor	68pF/50vdc ceramic		4	
9	capacitor	2.2uF/35vdc tantalum		2	
10	Resistor	RESISTOR, 0.25W 5% 3K3		4	
11	Resistor	RESISTOR, 0.25W 5% 2K2		2	

12	Resistor	RESISTOR, 0.25W 5% 10K		22	
13	Resistor	RESISTOR, 0.25W 5% 1K8		20	
14	Resistor	RESISTOR, 0.25W 5% 1M		4	
15	Resistor	RESISTOR, 0.25W 5% 560R		2	
16	Resistor	RESISTOR, 0.25W 5% 15K		10	
17	Resistor	RESISTOR, 5%, 1/4W 330R		10	
18	Resistor	RESISTOR, 0.25W 5% 330R		2	
19	Resistor	RESISTOR, 0.25W 5% 4K7		2	
20	Resistor	TRIMMER, 10K, 6MM		4	
21	potentiometer	5K		4	
22	Diode	zener diode 4.7v, **1N5337BG**		4	
23	LED	LED,yellow 2mA, 3mm		14	
24	LED	LED,red 2mA, 3mm		2	
25	LED	LED,green 2mA, 3mm		4	
26	Diode	1N4148		10	
27	schottky diode	1N5711		12	
28	filter	DSN6NC51H222Q55B		2	
29	quad comparator	LM339N, DIP14, 339		2	
30	opto coupler	SFH6106		4	
31	voltage regulator	5V		4	
32	header			5	
33	connector	2x8 Female connector		8	
34	connector	1x2 pin		2	
35	header	Double header		2	
36	connector	2x20		2	
37	connector	Rs-232,DB9 serial connector		2	
38	Power jack	3 pin		2	

39	Ribbon cable			2	
40	switch	Push button		2	
41	switch	2 position dip switch		2	
42	switch	SPDT toggle switch		4	
43	IC Base	2x7		4	
44	IC Base	2x2		2	